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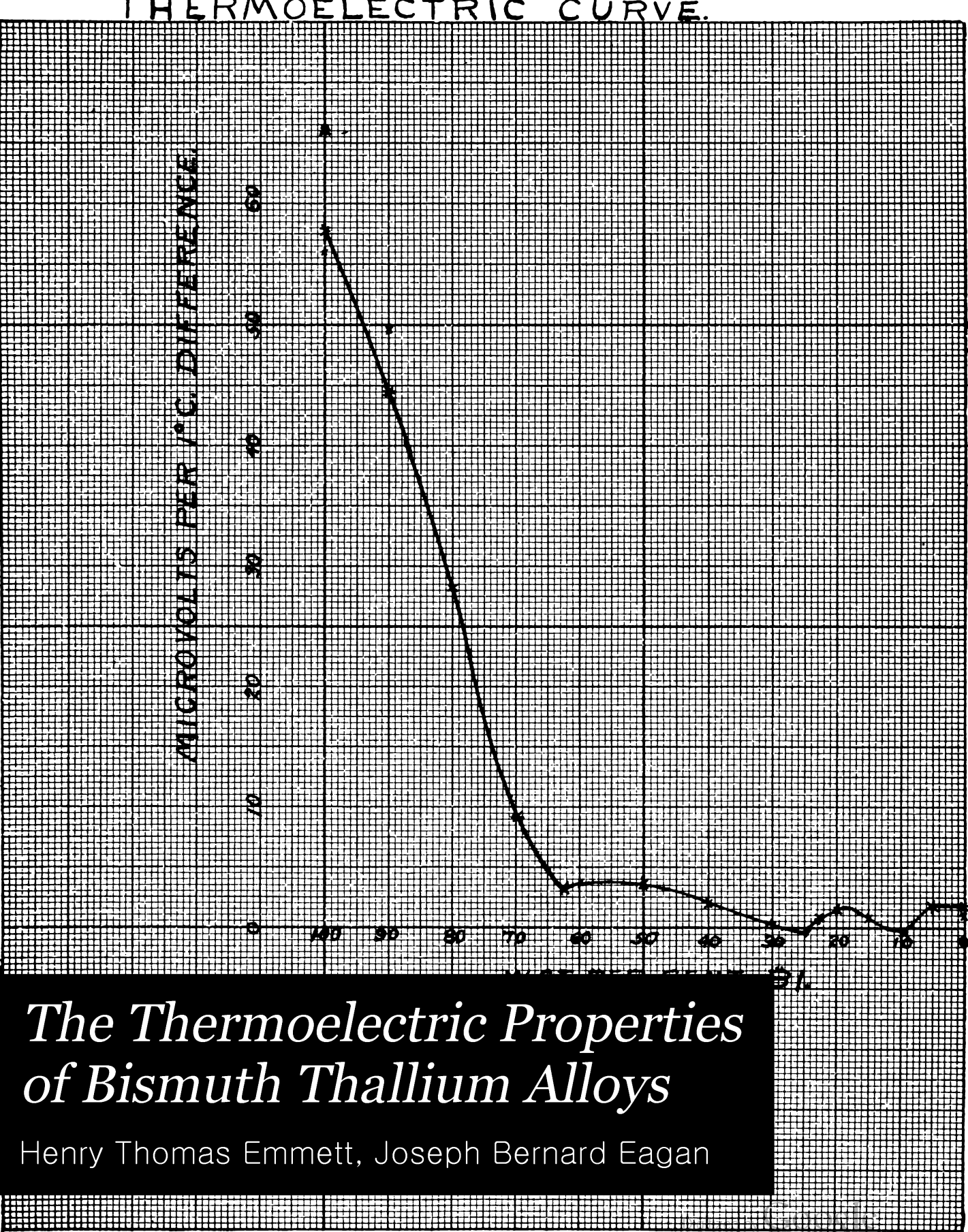

The Thermoelectric Properties of Bismuth Thallium Alloys

Henry Thomas Emmett, Joseph Bernard Eagan

Fig 2

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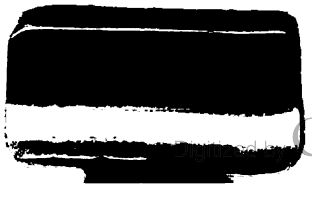

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THE THERMOELECTRIC PROPERTIES OF BISMUTH THALLIUM ALLOYS

A Thesis Submitted

by

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1913

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THE THERMOELECTRIC PROPERTIES OF BISMUTH THALLIUM ALLOYS.

When two conductors are joined together to form a circuit, a current flows in the circuit, if one junction is at a higher temperature than the other. This discovery by Seebeck in 1821, opened up a new field of investigation and the thermoelectric power of nearly all of the pure metals, has been determined as one part of a thermo-couple against lead, copper, or platinum, as a standard.

In the early 60's Becquerel[1] determined the thermoelectric heights of various alloys of the antimony-zinc and the antimony-cadmium series. He found that the curve connecting the thermoelectric heights and the concentration of one of the components of the alloy shows a peculiar point where a compound is formed. Recent investigations by Haken[2] of the thermoelectric heights of the following series of alloys, tellurium-antimony, tellurium-bismuth, tellurium-lead, antimony-silver, copper-phosphorus and bismuth-antimony, indicate that wherever compounds appear in these systems the curves connecting the thermoelectric heights with the concentration of one of the components show marked discontinuities. These effects were further corroborated by A. W. Smith[3], who determined the thermoelectric heights of the bismuth-antimo-

1. Ann. de Chem. et Phys. (4) 8 P 408, 1866.
2. Ann. der Phys. (4) 32 P 291, 1910.
3. Phys. Rev., Vol. 32, (178), 1911.

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ny, antimony-cadmium and antimony-zinc alloys in connection with the study of the Hall Effect in Alloys.

Mendenhall and Lent[1] determined the magnetic susceptibility of the bismuth-tellurium and bismuth-thallium series of alloys, and Whitford[2] later made a study of the electrical conductivity of the bismuth-thallium series. The present study was undertaken to determine the thermoelectric heights of the same series of alloys investigated by Whitford.

Kahlbaum's chemically pure bismuth, and Schuckhardt's chemically pure thallium were used. No chemical analysis was made of the alloys after fusion because other investigations have shown that the composition determined by the weights of the material put into the alloys checks closely with chemical analyses (Monkemeyer and Chikashige).[3]

The method of making the alloys was similar to that employed by Whitford. The metals were placed in a hard glass test tube, and fused under hydrogen pressure in an electric furnace. Two tubes passed thru the cork into the test tube, one to admit hydrogen, the other, which could be lowered into the metal, was attached to an aspirator so that the metal could be drawn up into the tube at the proper time. In order to insure a thorough mixture, the metals were kept

1. Phys. Rev., Vol. 32, (406), 1911.
2. Phys. Rev., Vol. 35, (144), 1912.
3. Zeitschrift f. anorg. Chem. 46, 415, 1905 & 51, 328, 1906.

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in a molten condition from ten to twenty minutes and the test tube was frequently shaken. In several cases the alloys were remelted.

The specimens ranged from 1 1/2 to 2 1/2 mm. in diameter and from 10 to 20 cm. in length. In most cases the glass was removed from the alloys by breaking it with a small hammer. Because of the brittleness of pure bismuth, the glass was removed from the ends of the specimens only.

The specimens were tested against pure copper. One end of each alloy was soldered to a strip of pure copper, and the other ends of the couple were connected to the potentiometer by copper leads. The junction was placed in a glass tube thru which steam was passed. In order to secure a uniform temperature, the steam tube was surrounded by a glass jacket thru which the steam was forced to return, thus completely surrounding the tube containing the hot junction. The cold junctions were encased in ice baths, and the e.m.f. was measured by a Leeds & Northrop direct reading potentiometer which could be read directly to 0.05 of a microvolt and easily estimated to 0.01 of a microvolt.

The arrangement of the apparatus is shown in Fig. I, in which M represents the steam tube, N - the steam jacket, S - the tube by which the steam enters M, E - the exhaust for steam, I,I' - a cross section of ice baths, J - the hot junction, B and D - the cold junctions, T - the thermometer,

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P - the potentiometer and LL' the copper leads.

A thermometer was inserted in the steam tube with the bulb near to the hot junction, but as a large part of the stem was exposed to the outside air, the mercury never registered much above 98.5°C. Since an accurate reading would involve a stem correction, the barometric pressure was taken, and the temperature of the steam was assumed to be that of the boiling point of water for the given barometric pressure.

Difficulty was experienced in attempting to use ordinary solder to connect the hot junctions, as certain combinations of the alloys and the lead-solder formed Wood's metal, the melting point of which is lower than the boiling point of water under ordinary barometric pressure. Hence part of the alloy itself or else pure bismuth was used as a solder.

The following table shows the thermoelectric height of each specimen and its method of preparation. A graphical representation of these results is shown in Fig. 2. Fig. 3 shows the same results but the melting point curve from Monkemeyer and Chikashige,[1] the susceptibility curve from Mendenhall & Lent[2] and the electrical conductivity curve from Whitford[3] have been added.

The thermoelectric heights of specimens of pure bismuth and those of 90% Bi. varied greatly as did also the

1. Zeitschrift f. anorg. Chem. 46 - 415 - (1905).
2. Physical Rev., Vol. 32, (406) 1911.
3. Physical Rev., Vol. 35, (144) 1912.

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specimens of pure thallium to a less degree. This was probably due to a difference in crystallization, as no attempt was made to cool the alloys in a uniform manner. As soon as the alloy was drawn up into the tube, it was removed from the furnace and allowed to cool in the air of the room. The slight variations in the other mixtures of a given percentage were probably due to error in composition.

The thermoelectric curve shows discontinuities at both of the compounds, Bi_5Tl_3 and 10.9% Bi. and also at 25% Bi. The compound Bi_5Tl_3 shows a singularity on all of the curves in Fig. 3. The bend in the curve at the compound 10.9% Bi. agrees with the second maximum of the melting point curve, but none of the other curves in Fig. 3. shows a singularity at 25% Bi., altho a very decided bend occurs in the electrical conductivity curve at 30% Bi. Altho both of the pure metals, bismuth and thallium, are electro negative with respect to copper, the alloys of 25% Bi. and 10.9 Bi. are electro positive. Haken[1] found similar peculiarities in the alloys of the bismuth-tellurium series. He found that alloys up to 20% Bi. were electro positive with respect to copper ; those from 20% to 50% Bi. electro negative ; from 50% Bi. to 60% electro positive ; whlie those alloys containing more than 60% Bi. were electro negative.

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1. Annalen der Physik - 32 - 327.- 1910.

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Specimen Number	Per cent Bi. Weight	Method of Preparation	Microvolts per 1°C. temperature difference against Cu.
1	100.	Direct from powder	- 66.60
2	100.	" " "	- 56.89
46	100.	" " "	- 58.64
3	90.	Melted together	- 49.72
4	90.	" "	- 44.92
5	80.	" "	- 28.43
6	80.	" "	- 28.20
7	70.	" "	- 9.50
8	70.	" "	- 9.22
42	62.5	" "	- 3.33
43	62.5	42 remelted	- 3.12
44	62.5	Melted together	- 3.46
45	62.5	" "	- 3.43
9	60.	" "	- 3.79
10	60.	" "	- 3.71
31	60.	(9-10) melted together	- 3.94
11	50.	Melted together	- 3.53
12	50.	" "	- 3.57
32	50.	(11-12)remelted and mixed	- 3.49
33	50.	" " " " "	- 3.53
13	40.	Melted together	- 2.12
14	40.	" "	- 2.08
15	30.	" "	- 0.11
16	30.	" "	- 0.21
25	25.	Mixed 15 and 17	+ 0.48
26	25.	" " " "	+ 0.55
27	25.	Melted together	+ 0.10
28	25.	" "	+ 0.12
34	22.5	Mixed 27 and 18	- 0.63
17	20.	Melted together	- 1.26
18	20.	" "	- 1.25
29	15.	" "	- 0.84
30	15.	" "	- 0.81
23	10.9	" "	+ 0.28
24	10.9	" "	+ 0.28
19	10.	" "	+ 0.25
20	10.	" "	+ 0.24
35	5.	From 20 by adding Th.	- 1.57
40	5.	Melted together	- 1.77
41	5.	" "	- 1.80
21	.00	Direct from stick	- 1.07
22	.00	" " "	- 0.82
36	.00	" " "	- 0.95
37	.00	" " "	- 1.72
38	.00	" " "	- 1.44
39	.00	" " "	- 1.68

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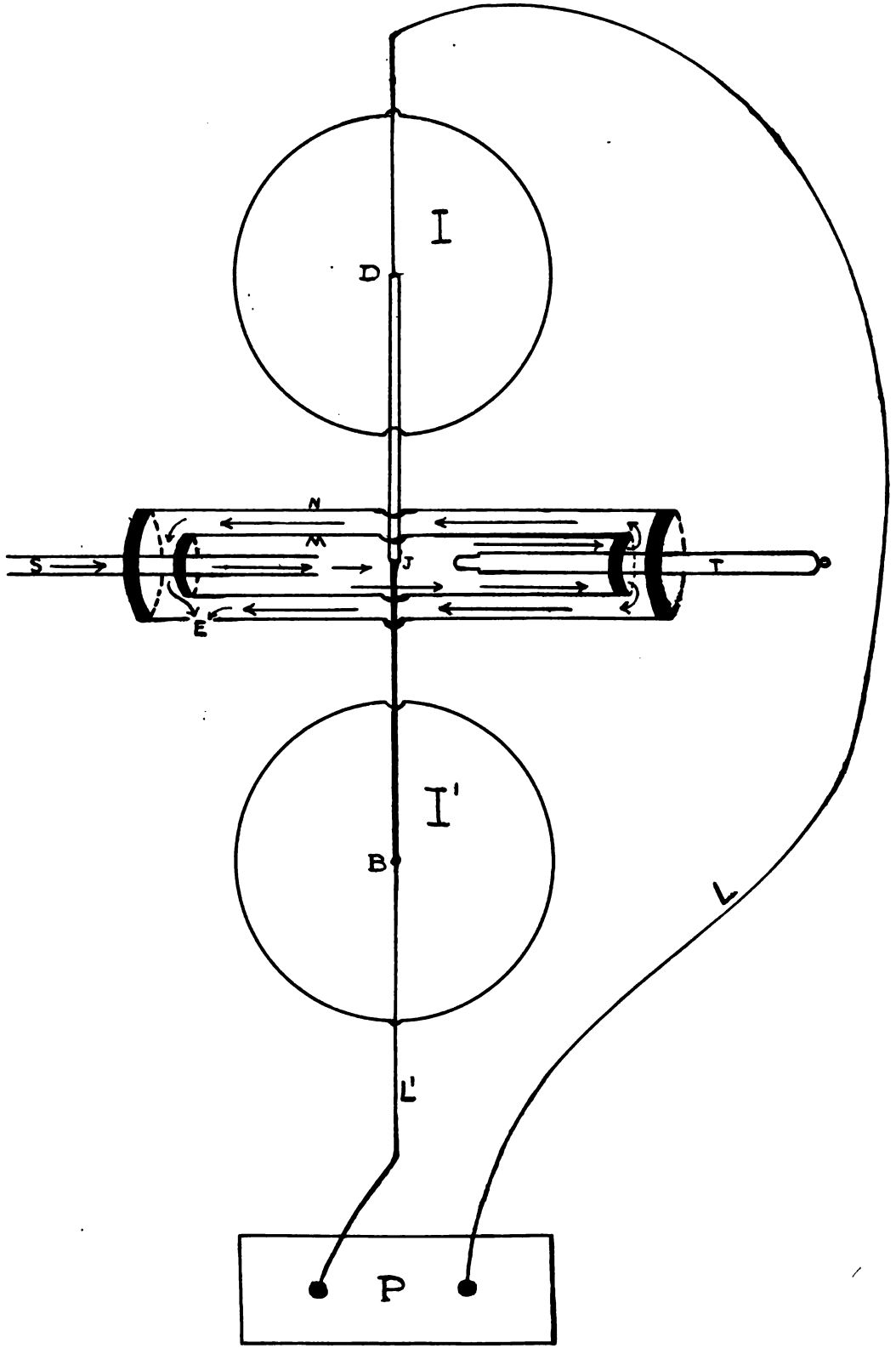

Fig. 1.

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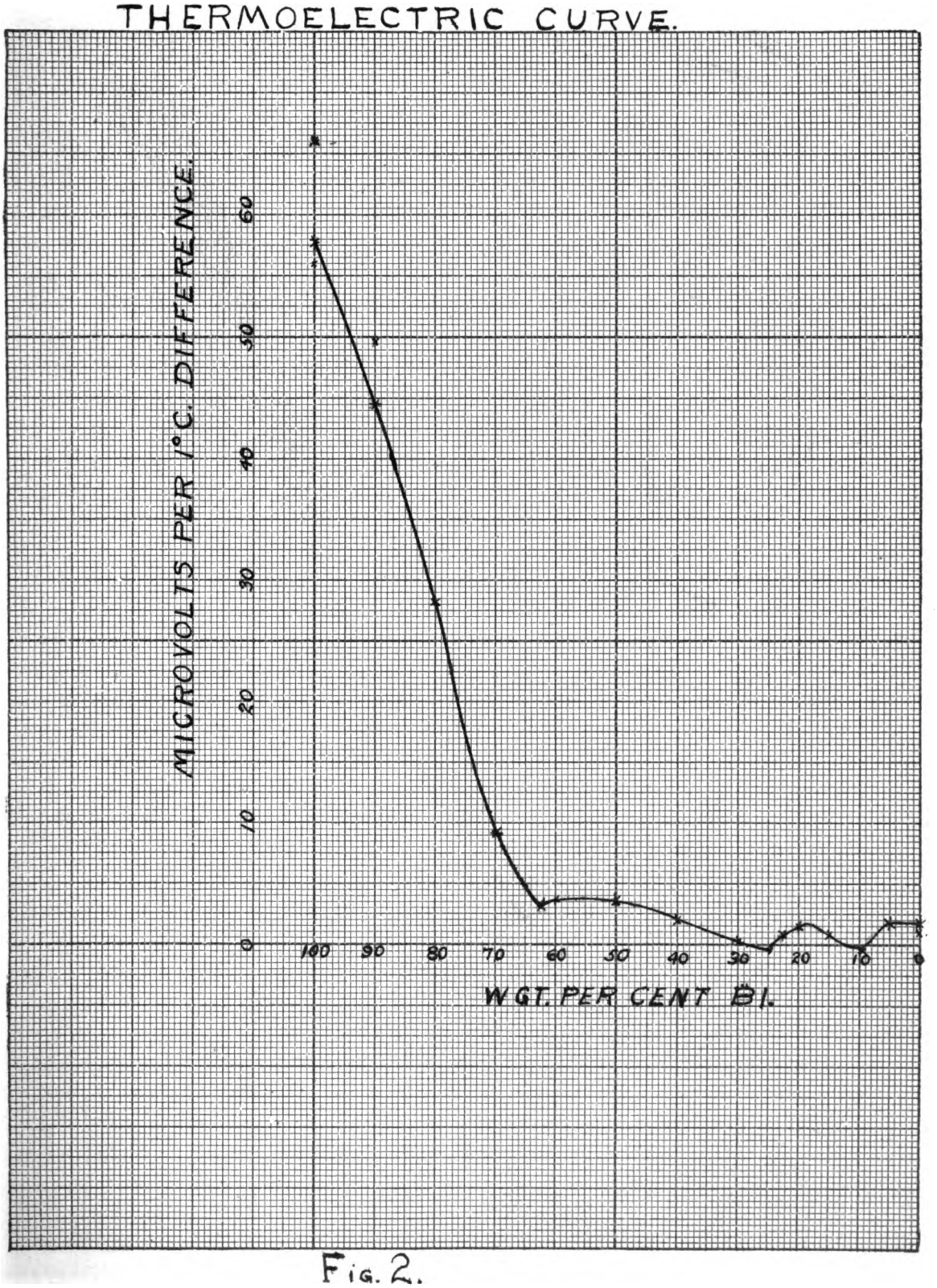

Fig. 2.

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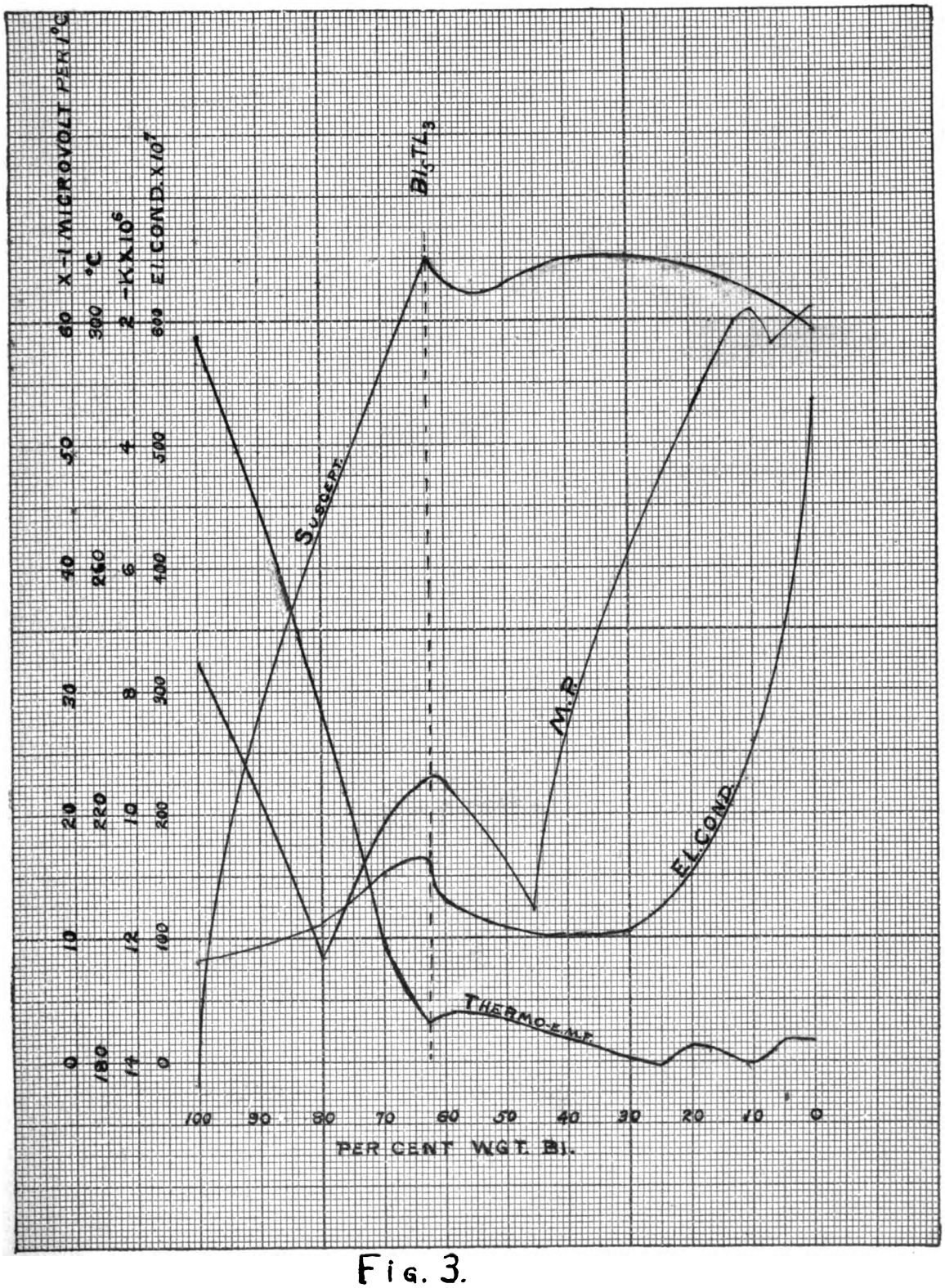

Fig. 3.

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APPROVED Earle M. Terry

Asst. Prof of Physics

June 9, 1913

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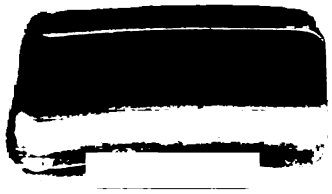

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